ONTARIO WATER RESOURCES COMMISSION

REPORT on WATER QUALITY in NEWBORO LAKES

1971

RECREATIONAL LAKES PROGRAM

THE

ONTARIO WATER RESOURCES COMMISSION

REPORT

ON

WATER QUALITY

IN

NEWBORO LAKES

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SUMMARY

A study to evaluate the status of water quality in the Newboro lakes was carried out during the summer of 1971.

The Newboro lakes lie in the Precambrian Shield. The shoreline is generally thinly covered with a variety of top soils ranging from fine sandy loams to coarse gravelly loams with black muck in the lower areas. The soil is exceedingly stony with rock outcrop dominating most of the shoreline. Due to the nature of the soils and the topography surrounding the lake, the soil can be considered as mostly unsuitable for cottage development utilizing standard subsurface septic tank systems.

In Newboro, Indian and Clear lakes, well-defined thermoclines or zones of rapid temperature declines were observed between the warm upper waters (eplimnia) and the cool bottom strata (hypolimnia) during the summer and early fall of 1971. During this period, depressed deep-water oxygen levels and elevated carbon dioxide concentrations resulting from decomposition of organic matter were measured. Throughout the entire summer in Newboro Lake and during August and September in Indian and Clear lakes, dissolved oxygen concentrations in the hypolimnia were not sufficient to maintain cold-water species of fish.

The water is relatively hard but has no unusual mineral characteristics. Surface values for pH were higher than bottom-water recordings while deep-water alkalinity concentrations were generally higher than those of the upper strata.

Surface concentrations of Kjeldahl nitrogen and total phosphorus were low and would not be expected to support nuisance levels of algae. There was evidence of nutrient recycling from the sediments but the ultimate effect on algae could not be clearly predicted.

Algal levels as measured by chlorophyll a concentrations were low during the three surveys. The algal densities recorded in the three lakes would not be expected to reduce water-oriented recreational activities such as swimming and water skiing or diminish the aesthetic quality of the lakes.

Newboro, Clear, Indian, Benson and Mosquito lakes had good bacteriological water quality; well-within the OWRC recreational use criteria during all three surveys. The only exception was Station 33A adjacent to Chaffey's locks which exceeded fecal streptococcus (FS) criteria for recreational use during the June survey.

The total coliform (TC) concentrations were highest in June, probably a result of the runoff following the heavy rainfall during the June survey.

In order to maintain the existing good water quality, every effort should be made to prevent any direct flow or leachate from domestic waste disposal systems or other sources of pollution from gaining access to the Newboro lakes.

INTRODUCTION

Maintenance of good water quality in recreational lakes in the Province of Ontario is of vital concern to the Ontario Ministry of the Environment and other governmental agencies involved in tourism and the control and management of shoreline development of cottages and resorts. In 1970 an interdepartmental program was established to survey a number of recreational lakes in order to detect and correct sources of water pollution and ensure that our lakes would be well managed to protect water quality. The Ontario Department of Health, whose jurisdiction in this program was transferred to the Ministry of the Environment in December 1971, would carry out on-shore inspection and correction of faulty private waste disposal systems, whereas the Ontario Water Resources Commission (now within the Ministry of the Environment) would evaluate the existing water quality of the respective lakes. A record of the present status of the private waste disposal systems and the lake water quality would also be documented for comparative use in any future studies.

Recreational lakes are subjected to two major types of water quality impairment; bacteriological contamination and excessive growths of algae and aquatic weeds (eutrophication). The two problems may result from a common source of wastes but the consequences of each are quite different. Bacteriological contamination by raw or inadequately treated sewage poses an immediate public health hazard if the water is used for bathing. In order for this to occur, these wastes must gain entry to the lake although it may not be obvious upon visual inspection of the site. It must be noted that no surface water is considered safe for human consumption without prior treatment including disinfection. The algae and weed growths impair aesthetic values and recreational use of a lake but seldom pose a health hazard. There are

nutrient sources other than sewage wastes which do not create serious bacterial hazards but do support nuisance plant growths such as agricultural fertilizer losses and normal nutrient runoff from forest and field.

In order to carry out its responsibility of evaluating the status of water quality in recreational lakes, the Ontario Water Resources Commission undertook a study on Newboro Lake (including Indian, Clear, Benson and Mosquito lakes) in the summer of 1971. Three surveys were conducted; a spring survey from June 18 to 22, a mid-summer survey from August 7 to 11 and a fall survey from September 29 to October 3 inclusive. These studies included the assessment of bacteriological, physical, chemical and biological conditions of the lake with stress being placed on the bacteriological and nutrient enrichment problems.

Sampling surveys were conducted on an intensive basis (sampling each day for a minimum of five days) which is mandatory for a reliable assessment of bacteriological conditions.

In addition to the results obtained from these studies, information from other governmental agencies has been incorporated in this report which is the Ontario Water Resources Commission's contribution to the Interdepartmental Task Force Report which will deal with the overall cottage pollution program in Ontario.

AREA DESCRIPTION

Geography and Topography

Newboro Lake is located in the Townships of North and South Crosby, Leeds County, approximately 35 kilometers (22 miles) west of Smiths Falls.

Loon, Mosquito, Benson, Indian and Clear lakes are in reality, bays of Newboro Lake, located in its west and south-west end. The lakes are separated from Newboro Lake by Scott Island and from each other by peninsulas off the mainland. The lakes have an irregular shoreline length of 172 kilometers (107 miles) which includes 61 kilometers (38 miles) of island shoreline. The maximum depth is 24 meters (78 feet) and the surface area of the lakes is 28 square kilometers (11 square miles).

The immediate watershed of the lake, excluding the waters flowing into it from Devil Lake and Upper Rideau Lake, consists of 114 square kilometers (46 square miles) of land characterized by steep slopes and rock outcrop. The two dominant soils surrounding the lake are the Monteagle sandy loam - Rock Complex and the Rockland Series. The Monteagle sandy loam - Rock Complex extends from the Rideau Canal at the Village of Newboro, west, along the north shore of Newboro and Loon lakes and the west shore of Loon Lake, the south shore of Mosquito Lake, surrounding Benson Lake and the west and south shores of Indian Lake. This soil complex consists of Monteagle sandy loam, Monteagle sandy loam - shallow phase, Muck, Christy sandy loam and several other of the sandy loam types. The soil is generally shallow and has a high percentage of rock outcrop. It is located on Precambrian bedrock composed of gneisses and schists. The content of medium and coarse sand in the till is high and there are many stones and boulders. It has a steeply sloping

topography. The water runs rapidly off the steep slopes and the portion that enters the soil, percolates readily through the porous soil materials. The Rockland series is located on all of the island in Newboro Lake, including Scott Island and along the north and south shores of Clear Lake, the east shore of Indian Lake, the peninsula forming the south-east shore of Loon Lake and the north-west shore of Mosquito Lake and the peninsula forming the north shore of Lucky Bay and the south-west shore.

The Bog is a series comprised of 50 to 90 per cent granite and granite gneiss thinly covered with a mixture of humus and sand overburden, with small deposits of deeper soil materials in the crevices. There is Farmington soil along the east shore of Clear Lake and between the Rideau Canal at the Village of Newboro and Bass Bay. This series has less than 30 centimeters of stone-free glacial till over a limestone bedrock. Although some of the area has no overburden, there is generally several inches of cover. The topography is gently sloping and the soil is well drained having a Brown Forest profile. The shoreline between Rosal Bay and the south shore of Lucky Bay belongs to the Grenville series which is a calcareous, sandy loam till over a limestone bedrock deposited in varying depths by melting ice. The soil is well drained, very stony and has a Brown Forest profile. The north-east shore of Newboro Lake belongs to the Muck series of soils. This series is made up of organic deposits found in old glacial spillway channels and other depressional areas. There are 46 centimeters (18 inches) or more of organic material overlying the mineral soil. The organic material is the partially decomposed remains of sedges and trees.

Climatic Range

The area has a mean daily temperature of -9°C (16°F) in January

and 20°C (68°F) in July. The mean annual precipitation is 84 centimeters (33 inches) including 203 centimeters (88 inches) of snow. According to meteorological reports, the area enjoys about 250 days yearly of no measurable precipitation. The summer climate is conducive to most recreational activities and the winter with its abundance of snow provides for participation in most winter sports.

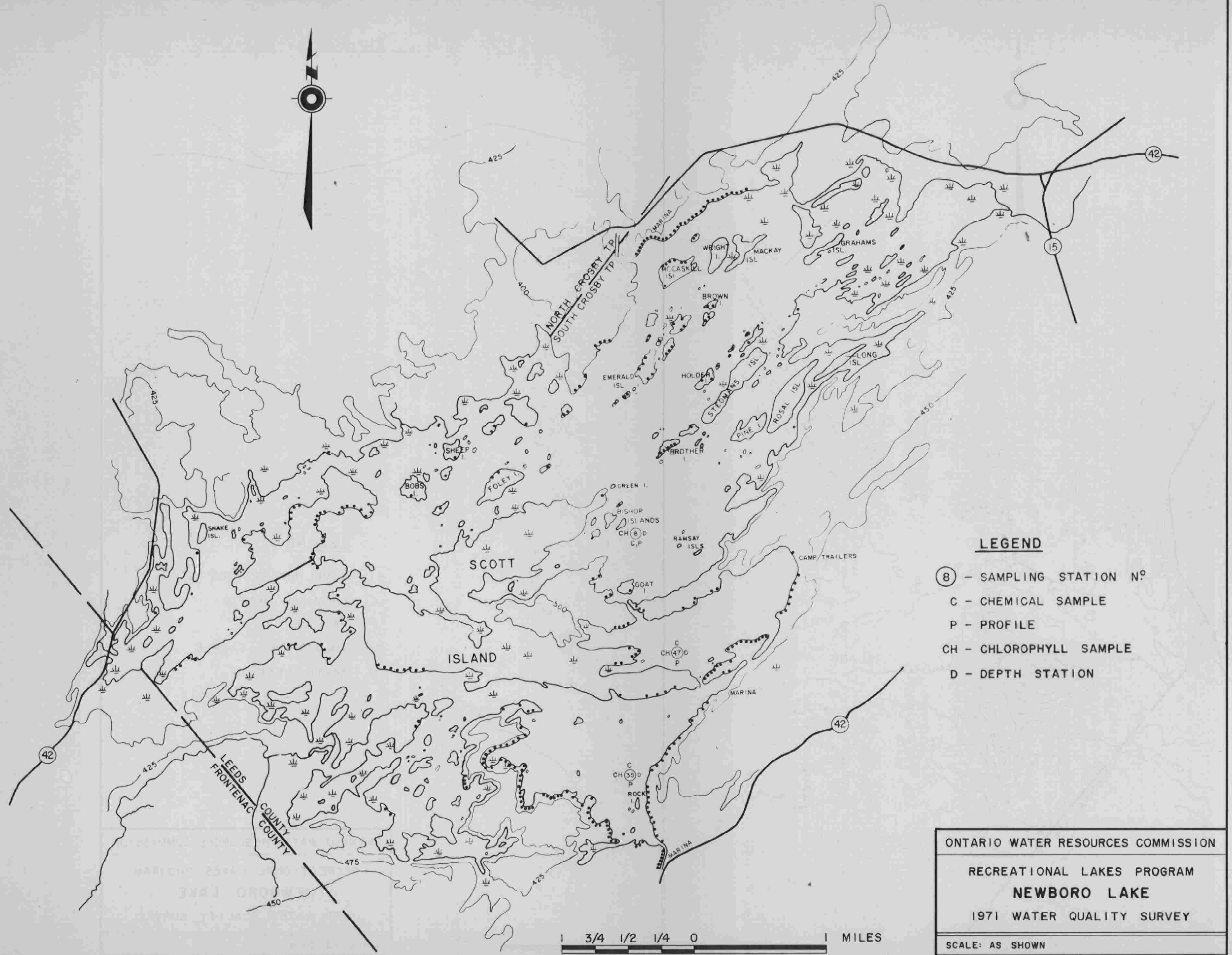
Water Movement

Newboro Lake lies in the St. Lawrence River Terminal Drainage Basin. It is fed by three inlets: Devil Lake which flows over a dam with a 9 meter drop (30 feet) at Bedford Mills and flows into the west end of Loon Lake; Sucker Creek, which flows into the east end of Newboro Lake; and the Rideau Canal which flows into Newboro Lake from Upper Rideau Lake. Lock 36 is located in the Rideau Canal at the Village of Newboro and has a drop of 2.4 meters (8 feet). The dam at the community of Bedford Mills is owned and operated by the Gananoque Electric Light Company. The only outlet is the Rideau Canal at the south end of Indian Lake which flows into Opinicon Lake. Lock 37 is located in the canal. It has a drop of 3.4 meters (11 feet).

Shoreline Development

Most of the 300 cottages on Newboro Lake are clustered together. Areas of dense cottage development are; at the Village of Newboro, the bay formed by the north and west shores of Leisures Point, the south-east shore of Clear Lake, and all but the north shore of Indian Lake (Figure 1). The remainder of the shoreline has scattered cottages and large areas of open shoreline. There are approximately 9 lodges on the lake and a trailer camp is located at the north-east end of Clear Lake.

FIGURE 1



ONTARIO WATER RESOURCES COMMISSION	
RECREATIONAL LAKES PROGRAM **NEWBORO LAKE** 1971 WATER QUALITY SURVEY	
SCALE: AS SHOWN	
DRAWN BY: P.L.	DATE: NOV., 1972
CHECKED BY:	DRAWING Nº: 72-75-DE

Water Usage

Most of the cottagers and the Village of Newboro use the lake water as their source of domestic water supply. The lake supports recreational water sports such as fishing, boating, water skiing and swimming. According to information available from the Ministry of Natural Resources, the lake offers a sport fishery of smallmouth bass, largemouth bass, walleye and northern pike. Some of the common and coarser fish in the lake are golden shiner, common shiner, spotfin shiner, rock bass, pumpkinseed, bluegill, yellow perch, yellow bullhead, brown bullhead, lake chub and rainbow smelt. There are two fish sanctuaries on Newboro Lake, the Iron Mine Sanctuary in Bass Bay and the Crosby Sanctuary in the Bog.

At present there are no direct discharges of raw or treated wastes into Newboro Lake from municipal or industrial sewage treatment facilities. The area residents are provided with a municipal solid waste disposal site located within 3.2 kilometers (2 miles) of the lake on parts of Lots 26 and 27, Concession I, South Crosby Township. This site does not appear to be posing any pollution hazard to the lake.

FIELD AND LABORATORY METHODS

Physical, Chemical and Biological Field Methods

Water quality surveys were conducted from June 19 to 22, from August 7 to 11 and August 15 as well as from September 29 to October 3. Two near-shore stations (1 and 33), which are near the major inlet and outlet, were selected for physical and chemical sampling. The mid-lake stations, Station 8 on Newboro Lake, Station 35 on Indian Lake and Station 47 on Clear Lake, were chosen for physical, chemical and biological sampling (Figure 1).

Dissolved oxygen and temperature profiles were determined daily in the field using a combination dissolved oxygen-telethermometer unit. Total alkalinity and free carbon dioxide were measured daily titrimetrically and pH was measured with a portable pH meter. Daily chlorophyll samples were collected in a 32-ounce bottle, at each mid-lake station, utilizing a composite sampler lowered through the euphotic zone (2X Secchi disc) and immediately preserved with 10-15 drops of a 2% $MgCO_3$ suspension.

Once per survey, a 32-ounce sample for hardness, alkalinity, chloride, total phosphorus, total Kjeldahl nitrogen, iron and conductivity was collected at all mid-lake stations. As well, at least two samples were collected at both the major inlet and outlet. The mid-lake stations were sampled using a composite sampler lowered through the euphotic zone. At the inlet and outlet, samples were collected from 1 meter of depth using a Kemmerer sampler.

At each mid-lake station one sample for total phosphorus, total Kjeldahl nitrogen and iron was obtained by means of a Kemmerer sampler from a depth of 1 meter above the bottom on September 30.

Physical, Chemical and Biological Laboratory Methods

All analyses were carried out using routine OWRC methods based on Standard Methods 13th Edition.

Iron was measured after the sample had been digested with acid to dissolve all forms of iron present.

Kjeldahl nitrogen and total phosphorus concentrations were determined after the sample was digested with acid and an oxidizing agent to destroy organic matter.

For chlorophyll determinations, 1 litre samples were filtered through a 1.2 u membrane filter which was then extracted with 90% acetone for 24 hours. Absorbance of the extract was determined at wavelengths of 600 to 750 mu using a Unicam SP1800 ultra violet spectrophotometer. The concentrations of chlorophyll _a_ were calculated using the equation given by Richards & Thompson (1952).

Bacteriological Field and Laboratory Methods

Five-day intensive bacteriological surveys were completed in June, August and September-October on the Newboro Lake area. In June and August 51 stations were sampled daily, including three depth stations at 8D, 35D and 47D. In September-October, 45 stations were sampled daily, including the three depth stations. In the fall survey, Stations 23 to 28 inclusive, were not surveyed.

Surface samples were collected at a depth of one meter below the surface using sterile, autoclavable polycarbonate 250 ml bottles. Depth samples were collected one meter above the bottom using a modified "piggy back" sampler and sterile 237 ml evacuated rubber air syringes.

All samples were stored on ice and delivered to the mobile laboratory within two to six hours and analyzed for total coliforms, fecal coliforms and fecal streptococcus using the membrane filtration technique (MF) (Standard Methods, 13th Edition) except that m-Endo Agar Les (Difco) was used for total coliform and MacConkey membrane broth (Oxoid) was used for fecal coliform determinations. The total coliforms (TC), fecal coliforms (FC) and fecal streptococcus (FS) were used as "indicators" of fecal pollution. The "indicators" are the normal flora of the large intestine, and are present in large numbers in the feces of man and animals. When water is polluted with fecal material, there is a potential danger that pathogens or disease causing micro-organisms may also be present.

The coliform group is defined, according to Standard Methods, 13th Edition, as "all of the aerobic and facultative anaerobic, gram-negative,

non-sporeforming rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C" and, or "all organisms which produce a colony with a golden-green metallic sheen within 24 hours of incubation" using the MF technique. This definition includes, in addition to the intestinal forms of the Escherichia coli group closely related bacteria of the genera Citrobacter and Enterobacter. The Enterobacter - Citrobacter groups are common in soil, but are also recovered in feces in small numbers and their presence in water may indicate soil runoff or, more important, less recent fecal pollution since these organisms tend to survive longer in water than do members of the Escherichia group, and even to multiply when suitable environmental conditions exist. A more specific test for coliforms of intestinal origin is the fecal coliform test, with incubation of the organisms at 44.5°C. Though by no means completely selective for Escherichia coli, this test has proved useful an an indicator of recent fecal pollution.

Fecal streptococci (or enterococci) are also valuable indicators of recent fecal pollution. These organisms are large, ovoid, gram-positive bacteria, occurring in chains. They are normal inhabitants of the large intestine of man and animals, and they generally do not multiply outside the body. In waters polluted with fecal material, fecal streptococci are usually found along with coliform bacteria, but in smaller numbers, although in some waters they may be found alone. Their presence, along with coliforms, indicates that at least a portion of the coliforms in the sample are of fecal origin.

Bacteriological Statistical Methods

Fluctuations in bacterial concentrations due to changing environmental conditions require that a great number of samples be taken to arrive at a mean value which is representative of a specific sample location or sampling area. The most appropriate mean for bacterial levels and this type of data is the

geometric mean. The vast quantities of bacteriological data generated from these samples necessitated the development of additional statistical methods to summarize the mean results into a more concise presentation. The statistical methods used are based on the analysis of variance. The stations within the same statistical bacterial level, without the bias normally associated with manual interpretation.

The analysis of variance is particularly effective where bacterial concentrations vary slightly throughout the lake. Areas or stations with slight differences in bacterial concentration may be isolated. Areas or stations with statistically higher bacterial numbers reliably indicate an input.

The results from all the analyses were organized as replicates representing the stations during the survey period. All data were transformed to logarithms (base 10) and all further analyses were done using these transformed data. A geometric mean (the antilogarithm) was calculated on each station and for each parameter. The validity of the analysis of variance program (ANOVA-CRE; Burger, 1972), was based on the assumptions that the variances of all the stations were similar (Bartlett's test of Homogeneity) and that the data were normally distributed.

Both of these assumptions were checked on the Newboro Lake area. The Bartlett's test was found to be non-signficiant and the data followed a normal distribution, hence the analyses of variance (F-test, Sokal, 1969) was calculated on all stations.

If the F was significant, then the multiple-t test was used to help determine the stations which should be deleted from the overall group to yield

a homogeneous group of stations. The withdrawn stations were regrouped with respect to geographic proximity and similar means. The calculations on all groups were repeated using the analysis of variance program until each discrete group was homogeneous. The homogeneous groups that were geographically isolated were compared by means of the Student-t test (using the log GM and S.E.) which indicated the statistical difference between these groups. The Student-t test was also used to compare the grouped bacteriological data from the three surveys.

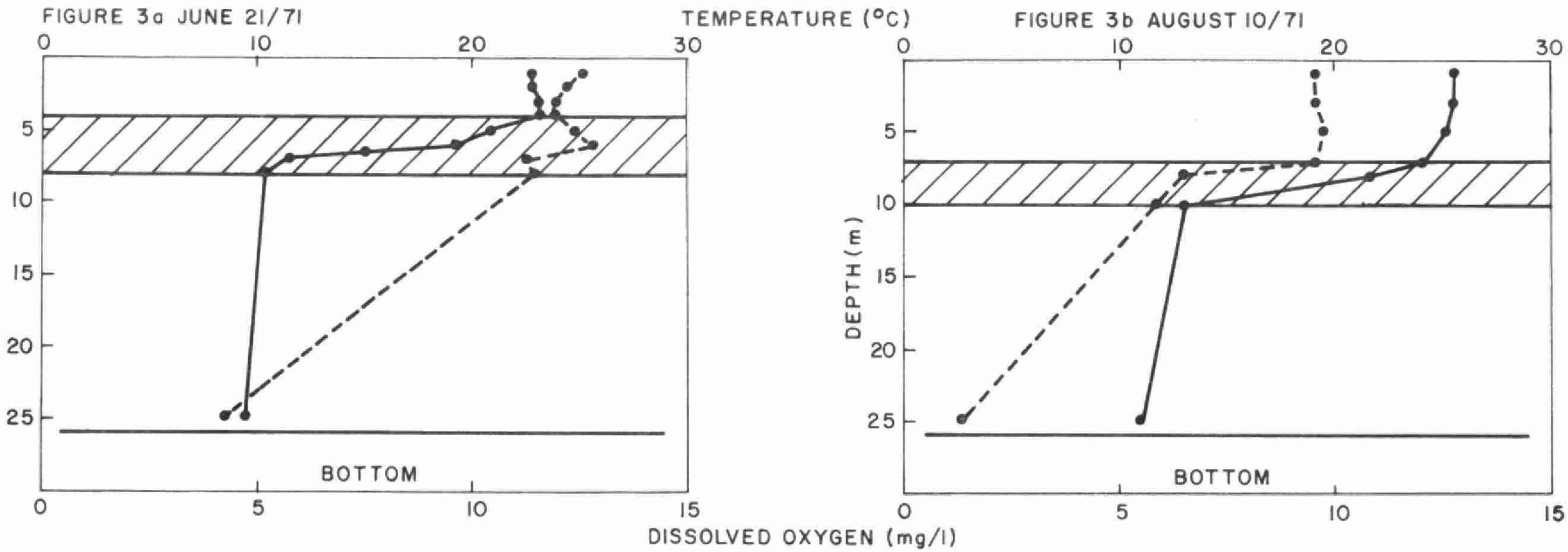
DISCUSSION OF RESULTS

Temperature and Dissolved Oxygen

In June, a well-defined thermocline or zone of rapid temperature decline was apparent between 3.5 and 8.5m in Newboro, Indian and Clear Lakes (Figures 2a, 3a and 4a respectively). The thermocline serves as a physical barrier to mixing between the upper warm waters (epilimnion) and the bottom cool waters (hypolimnion). In Newboro Lake, dissolved oxygen concentrations declined through the thermocline and were as low as 0.6 mg/l at 1m above bottom (Figure 2a). In Indian and Clear Lakes the deep-water dissolved oxygen concentrations were not as critical as in Newboro Lake (Figure 3a and 3b). These deep-water oxygen deficits resulted from bacterial oxidation of organic matter, biological respiration and chemical oxidation.

In August, the thermoclines in the three lakes were slightly deeper than in June (Figures 2b, 3b and 4b). Additionally, the oxygen regimes of the epilimnia and thermoclines were considerably lower than those recorded during the June survey. Finally, concentrations of dissolved oxygen immediately above bottom in Indian and Clear Lakes were lower than those observed in June.

By the end of September the thermocline were substantially lower than in the preceding survey (Figures 2c, 3c and 4c). This phenomenon as well as the cooler surface water temperatures were in keeping with the expected seasonal changes characteristic of many small inland recreational lakes. Severe dissolved oxygen declines from 13.5 to 1.2 mg/l in Newboro Lake, from 13.5 to 4.0 mg/l in Indian Lake and from 13.7 to 5.0 mg/l in Clear Lake were apparent through the thermocline. During most of the summer months in Newboro Lake and during August and September in Indian and Clear lakes dissolved oxygen concentrations in the hypolimnia were not sufficient to maintain cold-water



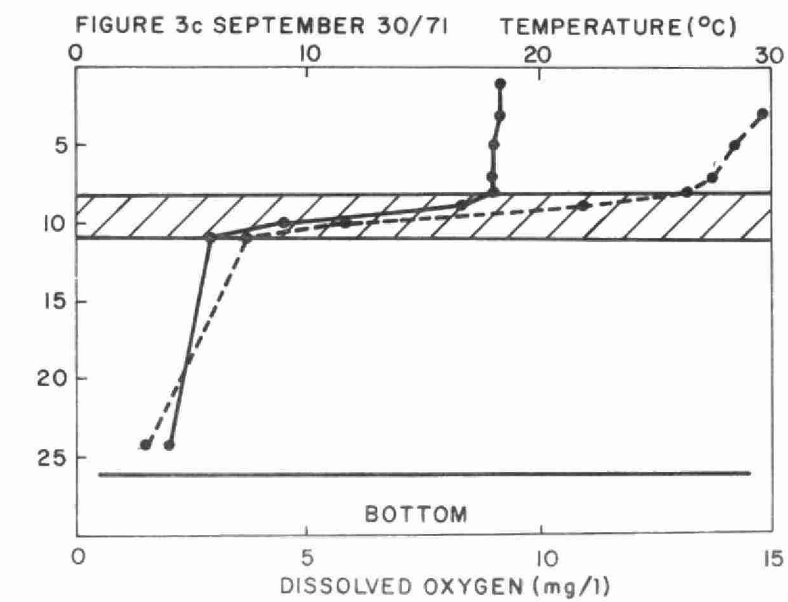


FIGURE 3: TEMPERATURE AND DISSOLVED OXYGEN PROFILES IN INDIAN LAKE STATION 35. THE SHADED AREA APPROXIMATES THE POSITION OF THE THERMOCLINE.

●——● TEMPERATURE

●----● DISSOLVED OXYGEN

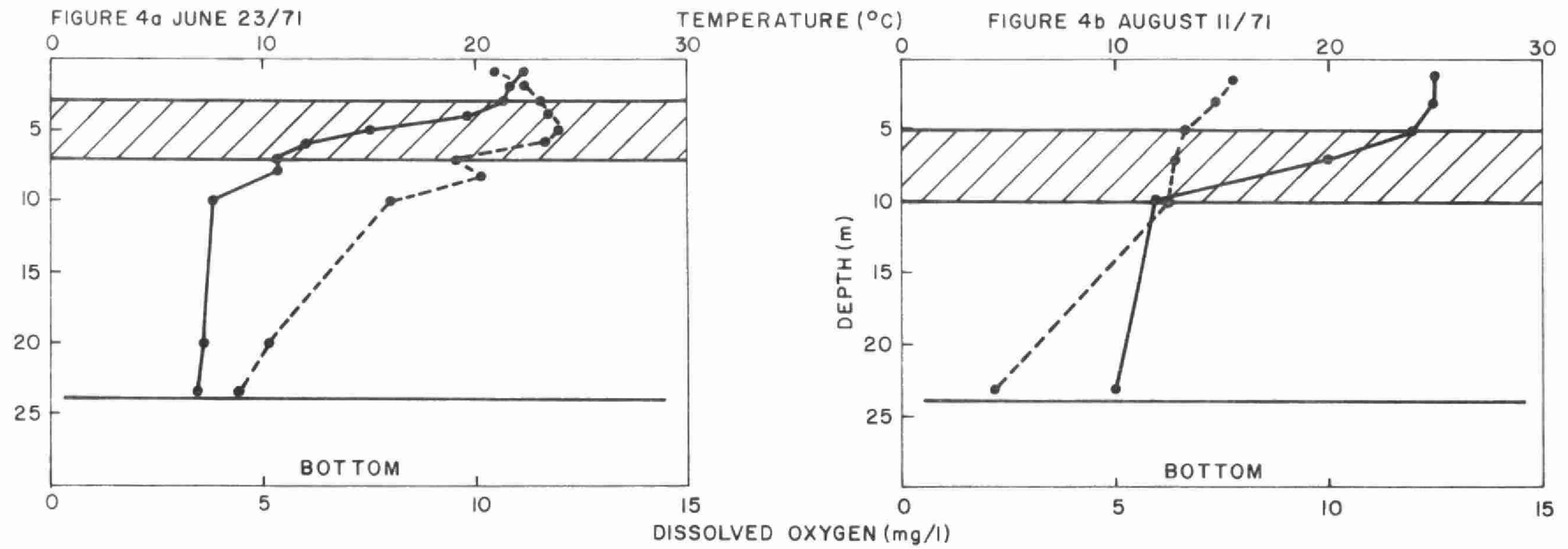


FIGURE 4: TEMPERATURE AND DISSOLVED OXYGEN PROFILES IN CLEAR LAKE STATION 47. THE LINE (— -- —) IN FIGURE 4c IS AN APPROXIMATION. THE SHADED AREA APPROXIMATES THE POSITION OF THE THERMOCLINE.

●——● TEMPERATURE
●- - -● DISSOLVED OXYGEN

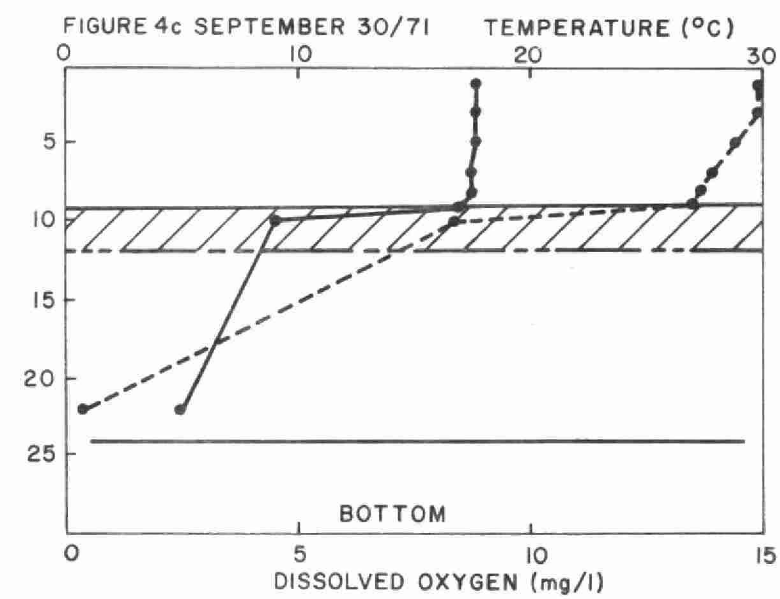


FIGURE 2a JUNE 20/71

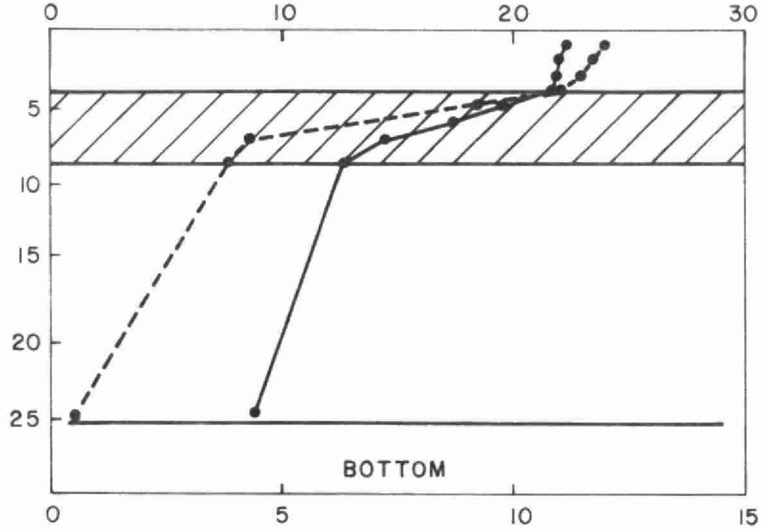


FIGURE 2b AUGUST 9/71

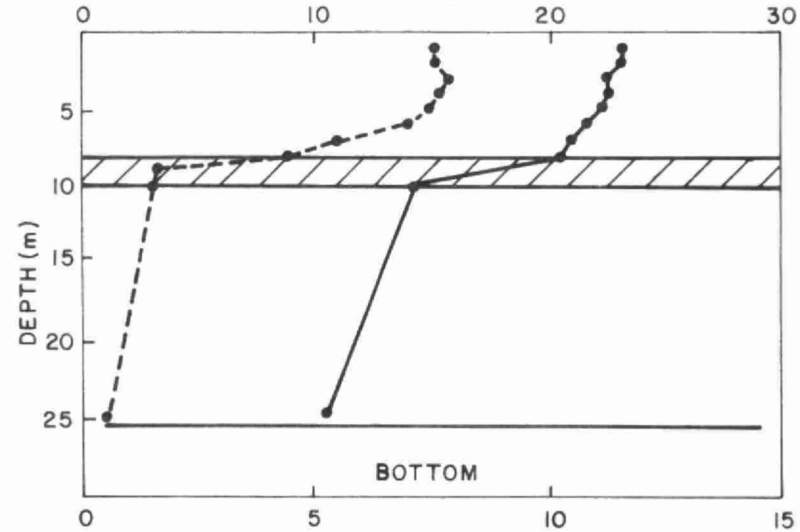
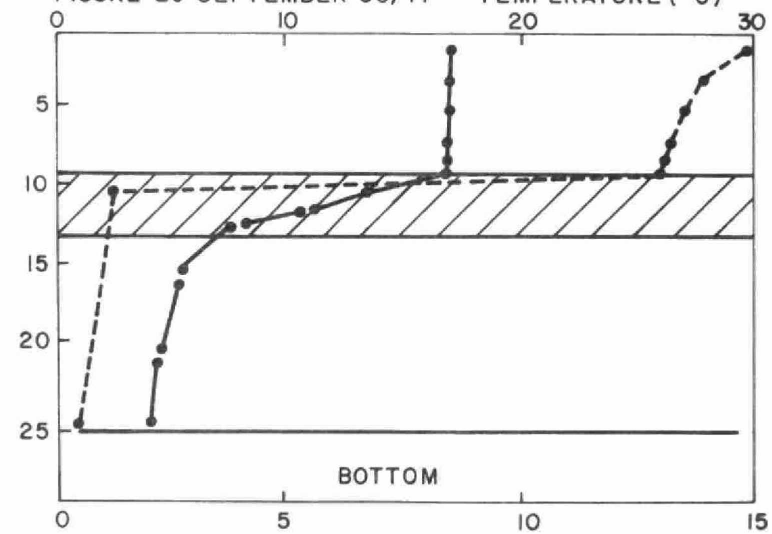


FIGURE 2: TEMPERATURE AND DISSOLVED OXYGEN PROFILES IN NEWBORO LAKE STATION 8. THE SHADED AREA APPROXIMATES THE POSITION OF THE THERMOCLINE.

- TEMPERATURE
- DISSOLVED OXYGEN
- APPROXIMATION

FIGURE 2c SEPTEMBER 30/71



species of fish such as lake trout, whitefish and herring.

pH, Free Carbon Dioxide and Total Alkalinity

In the three lakes, surface pH values were higher than in the deeper strata (Table 1). For example, on August 8, 1971 at Station 8 in Newboro Lake, pH values at 1 and 22m were 8.3 and 7.0 respectively.

Carbon dioxide concentrations in the surface waters were zero or near-zero while those of the bottom strata ranged between 5.8 and 33.5 mg/l (Table 1). The high deep-water carbon dioxide values as well as the above mentioned depressed pH values are related to conditions of organic decomposition.

In general, alkalinity concentrations were higher in the bottom waters than in the surface waters (Table 1). For example, on September 29 at Station 8 (Newboro Lake) values at 1 and 23m were 106 and 188 mg/l respectively. The higher total alkalinity values in the bottom waters relative to surface concentrations indicate that release of bicarbonate from sediments was occurring by bacterial and chemical action in conjunction with calcium, magnesium, iron, manganese and ammonia.

Hardness, Chloride, Conductivity and Iron

The hardness, chloride and conductivity data (Table 2) were consistent with each other indicating that no unusual mineral characteristics were present. The water is sufficiently hard that detergents containing phosphorus are desirable for washing purposes. If such detergents are used by cottagers, every effort should be made to ensure that the waste disposal system does not allow any phosphates to gain access to the lake.

The iron concentrations (Table 2) were uniformly low which is normal for this type of lake.

Kjeldahl Nitrogen and Total Phosphorus

The surface concentrations of Kjeldahl nitrogen and total phosphorus (Table 2) were low and would not be expected to support nuisance levels of algae.

There were high concentrations of each in the bottom waters at Stations 8, 35 and 47. These high concentrations are likely due to recycling from the sediment. The great depth of water will retard the return of this material to the surface and will also reduce any growth effects on algae by dilution. Therefore, while there is a potential source of nutrients in the bottom waters, its ultimate effect on algal growth is not clearly predictable.

Chlorophyll a

In general, algal densities in Newboro, Indian and Clear Lakes as reflected by chlorophyll a concentrations were low during the three surveys (Table 3). Populations in Newboro Lake were slightly higher than those measured in Indian and Clear Lakes. The algal levels encountered would not be expected to cause a reduction in water-oriented recreational activities such as swimming

and water skiing or diminish the aesthetic quality of the lake.

As indicated earlier, chlorophyll a measures the amount of photosynthetic green pigment in algae while water clarity which is one of the more important parameters used in defining water quality is determined using a Secchi disc. Recently, Brown (1972) has indicated that a near-hyperbolic relationship exists between chlorophyll a concentrations and Secchi disc readings for lake of Precambrian origin. Figure 5 describes the author's mathematical relationship between chlorophyll a and Secchi disc for 945 sets of data collected from approximately sixty recreational lakes located primarily in southern Ontario. Points for eutrophic lakes which are characterized by high chlorophyll a concentrations and poor water clarity are situated along the vertical axis of the hyperbola while oligotrophic waters which have low chlorophyll a levels and allow significant light penetration be along the horizontal limb. Mestrophic lakes would be dispersed about the middle section of the curve.

The relatively unproductive nature of the "Newboro Lakes" is indicated by their proximity to values computed for Lake Ontario and the Eastern Basin of Lake Erie - two oligotrophic to mestrophic bodies of water. Significantly, Newboro, Indian and Clear Lakes are well-removed from the Bay of Quinte, the Western Basin of Lake Erie, Riley Lake and Gravenhurst Bay - four highly enriched lakes.

Bacteriology

With the exception of Station 33A, exceeding the FS criteria in June, the Newboro Lakes were within the bacteriological criteria for total body contact recreational use (OWRC, 1970) during all three surveys.

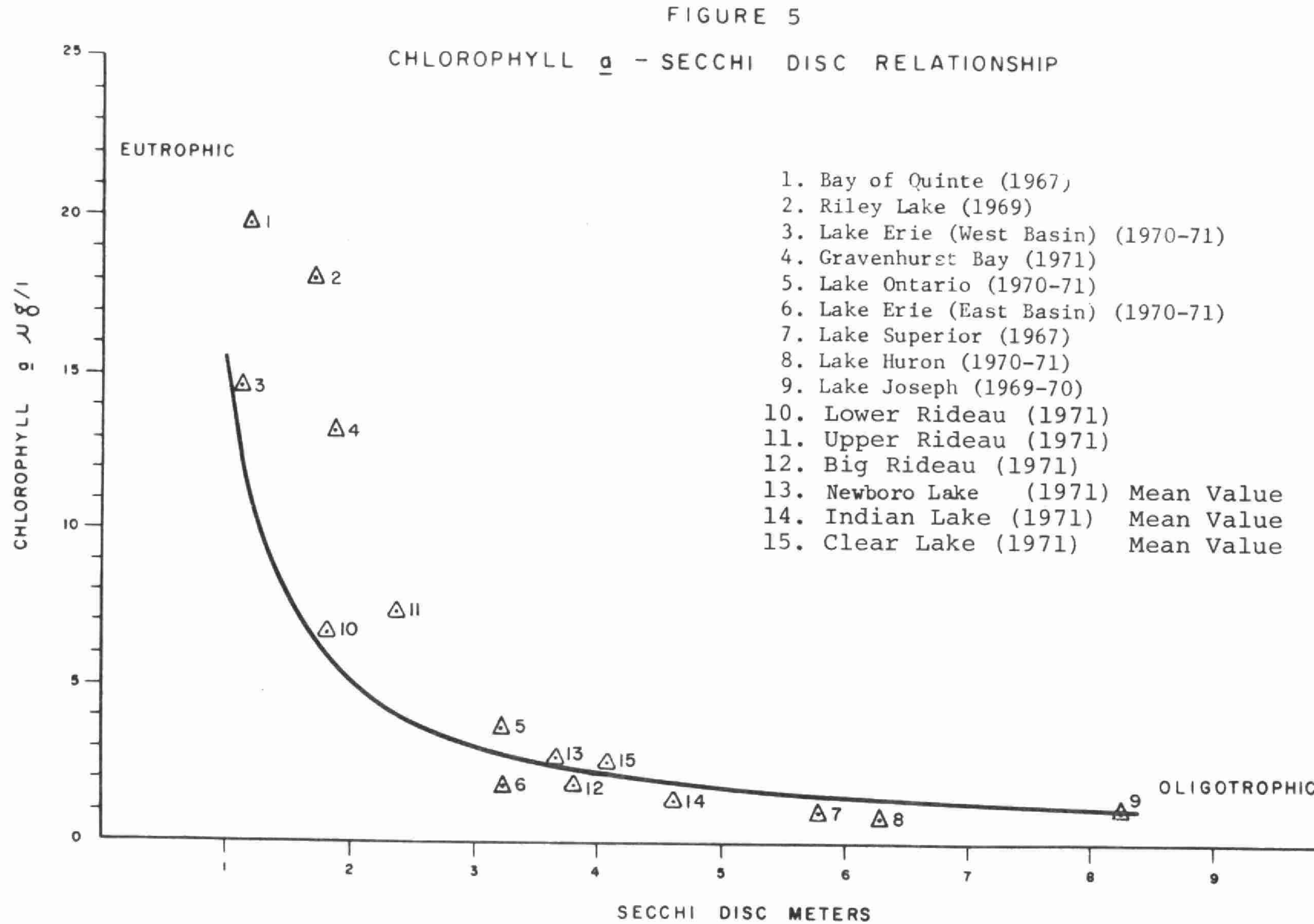


Figure 5: The relationship between chlorophyll a and Secchi disc as determined from the recreational lakes surveyed in 1971, as well as the mean values for chlorophyll a - Secchi disc for Newboro, Indian and Clear Lakes. The values for the Great Lakes were added for comparative purposes.

In June all stations displayed homogeneously low FC levels of 1/100 ml (Figure 6). Station 33A, at the heavily developed outlet at Chaffey's Locks, exceeded the FS criteria with 23/100 ml. The remainder of the lake area had a low FS mean of 2/100 ml (Figure 6). In June, the lake area was divided into five areas based on TC concentration as well as five isolated stations with differing TC densities. Group D, in the north-west section of Newboro Lake displayed the highest TC density of 853/100 ml, largely due to the the high TC levels on June 26, 27 and 28 following the heavy rainfall on June 25 and associated runoff (1.03 inches were recorded at Kingston Climatological Station). Group A (Indian and Clear lakes) and Group C (eastern section of Newboro Lake) displayed geometric mean TC levels of 198/100 ml and 154/100 ml respectively, (Table 4a). Group B, adjacent to the Village of Newboro, had a low TC mean of 31/100 ml. Mosquito Lake (Section 2) which is shallow and weedy, had a homogeneously low TC mean of 65/100 ml. The three depth stations 8D, 35D and 47D were characterized by low TC means (Table 4a) of 3/100 ml, 4/100 ml and 2/100 ml respectively. The remainder of the Stations 6, 7, 40A, 49 had significantly different TC means of 286/100 ml, 53/100 ml, 72/100 ml, 47/100 ml respectively.

In August (Figure 7), section 1, which includes Newboro, Clear and Indian lakes with 13 TC/100 ml, 1 FC/100 ml, 3 FS/100 ml was non-significantly different from section 2, which includes Benson and Mosquito lakes with 8 TC/100 ml, 1 FC/100 ml and 2 FS/100 ml. However, in section 1, high TC counts exceeding the criteria were recorded on August 8, 9 and 10 in Newboro Lake (Stations 1, 2A, 3, 4, 5, 9, 11, 12, 13, 16, 21, 22, 40A), FS counts exceeding the criteria were recorded on August 11 at the following Stations: 4, 9, 6, 7, 8, 44, 40A.

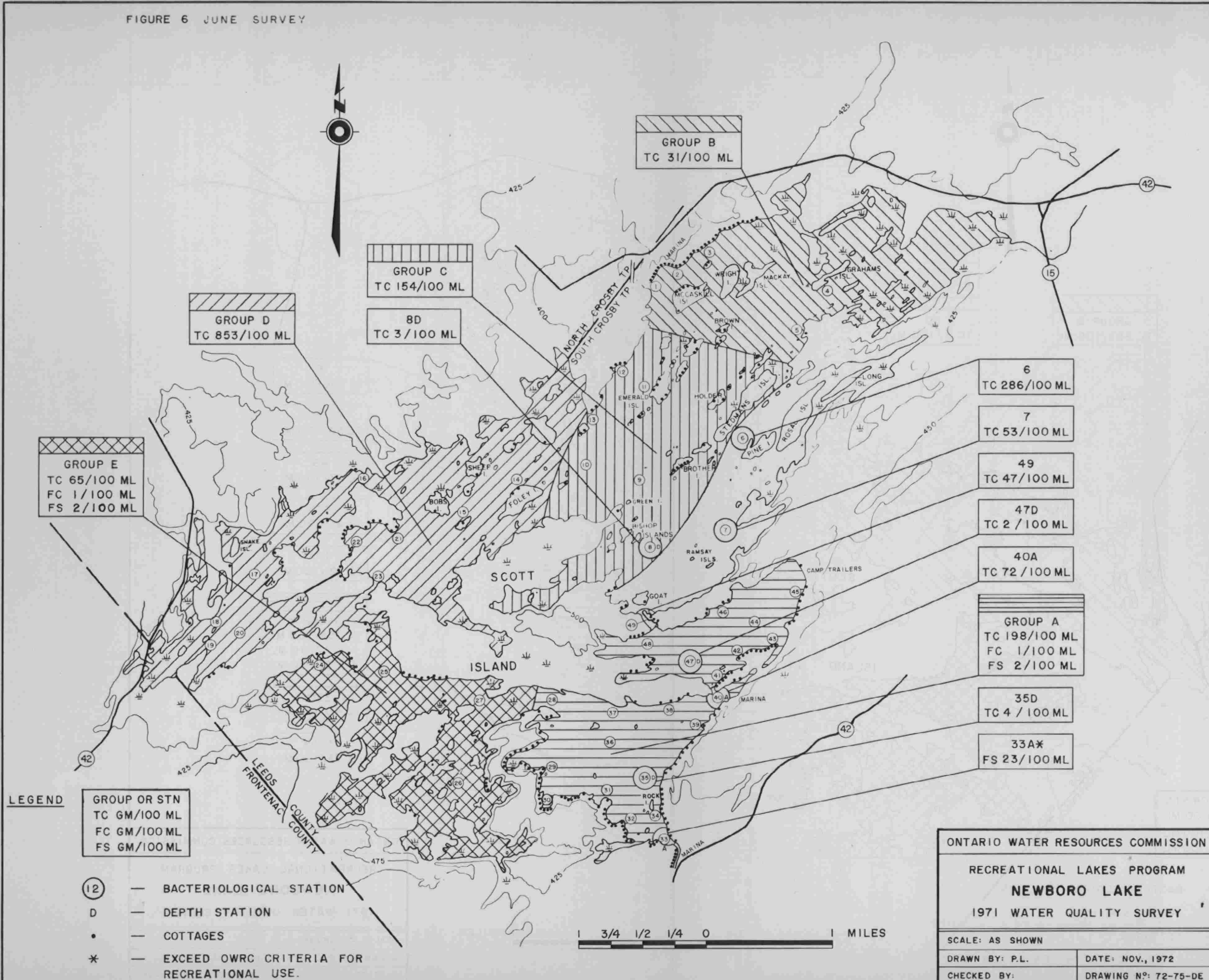
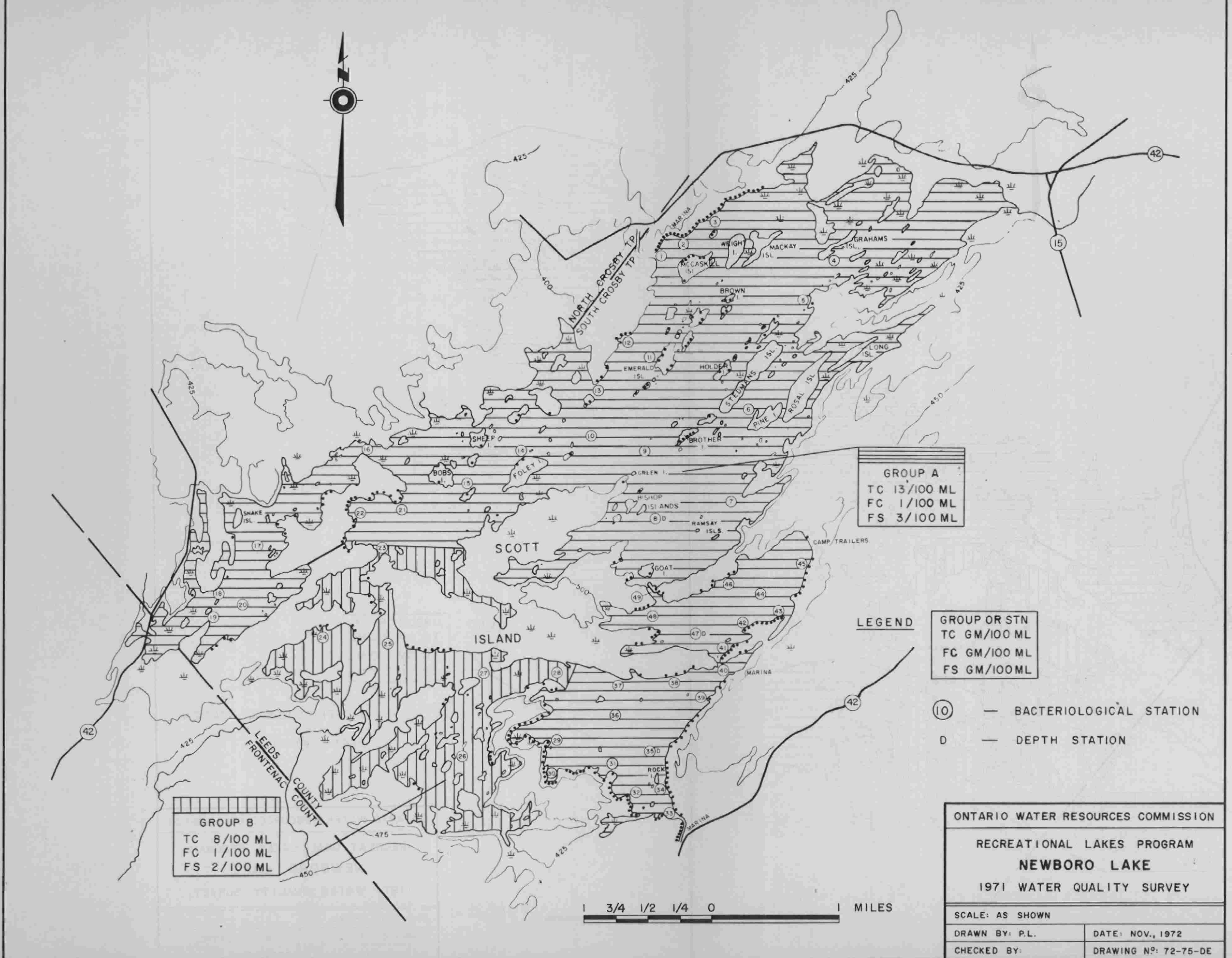


FIGURE 6 JUNE SURVEY

FIGURE 7 AUGUST SURVEY



In September (Figure 8), most of the stations had overall geometric means of 5 TC/100 ml, 1 FC/100 ml and 1 FS/100 ml. However, Group B and C adjacent to Newboro had significantly higher geometric means of 30 TC/100 ml and 4 FS/100 ml respectively. Station 33A, at Chaffey's Locks, displayed a significantly higher FS mean of 8/100 ml.

The TC concentrations were highest in June, then decreased significantly in August and September - October (Table 5a). FC and FS concentrations, with the exception of Station 33A, rained little during the three surveys.

Although the Newboro Lake area was well within the OWRC recreational use criteria, no surface water is considered potable without prior treatment including disinfection.

FIGURE 8 SEPTEMBER SURVEY

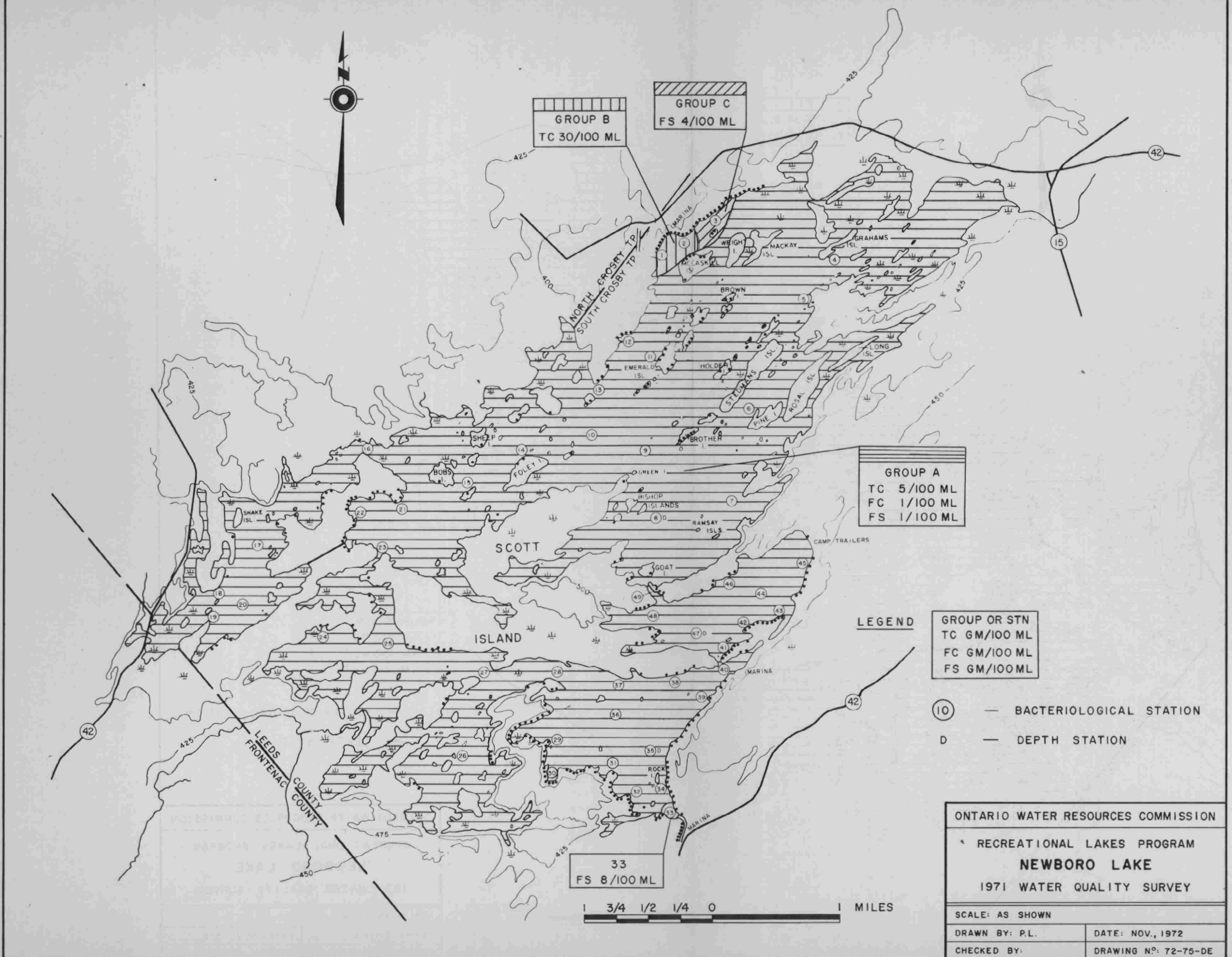


Table 1: Extreme and mean data for dissolved oxygen (mg/l), pH, alkalinity (mg/l) and free CO_2 (mg/l) for Newboro, Indian and Clear Lakes, 1971. Data were obtained from 1 metre and from 1 metre above the sediments.

LAKE	DISSOLVED OXYGEN		pH		ALKALINITY		FREE CO_2	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Newboro								
1m	7.4-15.4	12.3	8.3-8.6	8.4	92.5-132.0	106.2	0.0- 0.0	0.0
bottom	0.2- 1.9	0.8	6.9-7.5	7.2	135.0-210.0	176.9	13.4-24.4	19.5
Indian								
1m	7.0-16.2	11.8	8.4-8.8	8.5	78.5-101.3	85.1	0.0- 0.0	0.0
bottom	0.0- 6.2	2.2	6.6-7.5	7.1	77.0-107.0	96.0	5.8-16.0	10.5
Clear								
1m	7.8-16.2	12.5	8.3-8.8	8.5	96.5-112.5	103.9	0.0- 3.9	N.A.
bottom	0.2- 4.2	2.0	6.9-7.5	7.3	101.5-123.5	108.9	7.0-33.5	12.4

N.A. - only one reading for free CO_2 at 1m depth.

Table 2

Iron, Hardness (Hard), Total Phosphorus (P), Total Kjeldahl Nitrogen (N), Chloride (Cl) and Conductivity (Cond) for Newboro Lake, 1971.

Results are expressed in mg/l except conductivity which is umhos/cm^3.

Station	Depth	Date	Iron	Hard.	P	N	Cl.	Cond.
1	1m	20/6	0.10	106	0.026	0.46	8	-
1	1m	30/9	0.20	104	0.026	0.68	7	215
8	6.6m comp	20/6	0.05	114	0.022	0.50	8	-
8	9m comp	8/8	0.25	114	0.010	0.42	8	242
8	15m	10/8	-	-	0.28	0.55	-	-
8	10m comp	30/9	0.05	102	0.018	0.54	7	215
8	22m	30/9	0.10	-	0.11	1.5	-	-
35	8.4m comp	20/6	0.05	96	0.014	0.43	5	-
35	9m comp	8/8	0.05	96	0.013	0.40	5	201
35	25m	8/8	-	-	0.040	0.60	-	-
35	12m comp	30/9	0.05	96	0.014	0.44	6	196
35	25m	30/9	0.10	-	0.12	1.1	-	-
47	6m comp	21/6	0.05	112	0.012	0.44	9	-
47	22m	8/8	-	-	0.008	0.46	-	-
47	12m comp	30/9	0.05	104	0.014	0.36	7	220
47	22m	30/9	0.10	-	0.026	0.66	-	-
330	1m	20/6	0.05	96	0.022	0.48	5	-
330	1m	10/8	0.30	98	0.010	0.43	6	204
330	1m	30/9	0.05	96	0.012	0.38	6	195

means "less than"

"comp" means a composite sample taken through the depth indicated

Table 3: Chlorophyll a and Secchi disc values for Newboro, Indian and Clear lakes, Stations 8, 35 and 47 respectively, during 1971.

Date		Newboro Lake #8		Indian Lake #35		Clear Lake #47	
		Chloro. a	S.D.	Chloro. a	S.D.	Chloro. a	S.D.
June	19	1.9 µg/l	3.0m	- µg/l	- m	1.6 µg/l	4.2 m
June	20	3.5	3.0	-	-	2.2	4.0
June	21	4.5	3.0	3.1	3.0	1.8	4.0
June	22	4.1	4.5	3.9	3.0	1.8	4.5
August	8	1.4	4.0	2.0	4.5	1.8	4.5
August	9	2.4	4.5	1.7	4.2	1.4	4.0
August	10	1.6	3.0	3.0	4.5	1.2	4.5
August	11	2.1	-	2.1	-	1.4	-
August	15	-	-	2.3	4.5	2.5	4.5
September	29	1.2	3.0	1.1	5.0	1.0	4.0
September	30	1.4	5.0	1.0	6.0	1.3	6.0
October	1	1.5	3.5	1.1	5.0	0.8	5.0
October	2	1.3	5.0	1.4	6.0	1.4	5.5
October	3	1.5	3.2	0.9	5.0	1.0	5.0
MEAN		2.18	3.66	1.97	4.23	1.51	4.67

EXPLANATION OF TERMS IN BACTERIOLOGICAL TABLES

F - the calculated analysis of variance statistic on F ratio.

df - degrees of freedom of the F ratio for "between group" and "within group" variation.

F(5%) - the F ratio from a statistics table (Rohlf 1969). If the calculated F is greater than the F(5%), a significant difference (SD) occurred between the groups in the analysis. If the F is less than F(5%), no significant difference (NSD) occurred.

log GM - the logarithm (base 10) of the geometric mean.

S.E. - the standard error of the log GM where

$$S.E. = \frac{s}{\sqrt{n}} \quad \text{and } s = \text{standard deviation}$$

N - the number of values in the mean.

GM - the geometric mean of the bacterial level.

t - the calculated test of significance or student t-test used to compare stations, groups and a survey.

If t for the number of degrees of freedom shown is greater than the critical t value, a significant difference (SD) occurs.

SD refers to a significant difference at the .05 level but no significant difference at the .01 level.

SD* refers to a significant difference at the .01 level but no significant difference at the .001 level.

SD** refers to a significant difference at the .001 level.

Table 4a

Analysis of Variance Summary of Groups

Parameter - Total Coliform TC/100 ml

SURVEY	JUNE	AUGUST	SEPTEMBER-OCTOBER
Group	Section 1	Section 1	Section 1
F	6.830	1.454	1.541
df	46,183	44, 171	44, 134
F5%	1.463	1.465	1.482
	SD	NSD	SD
Group	A	Section 1	A
	Stations 28 - 48		All stations
F	1.110		0.973
df	21, 88		40, 122
F5%	1.87		1.505
	NSD		NSD
log GM	2.2955	1.1127	0.6509
SE	0.0355	0.0588	0.0480
N	110	216	163
GM	198	13	5
Group	B		B
	Stations 1 - 5		Stations 1, 2, 2A, 3
F	0.209		0.261
df	5, 24		3, 12
F5%	2.62		8.74
	NSD		NSD
log GM	1.4944		1.4738
SE	0.6467		0.1150
N	30		16
GM	31		30
Group	C		
	Stations 8 - 13		
F	2.456		
df	5, 24		
F5%	2.62		
	NSD		
log GM	2.1880		
SE	0.0637		
N	30		
GM	154		

Table 4a - continued

SURVEY	JUNE	AUGUST	SEPTEMBER-OCTOBER
Group	D		
	Stations, 14, 16, 21 - 23		
F	0.4051		
df	5, 24		
F5%	2.62		
	NSD		
log GM	2.9310		
SE	0.0784		
N	30		
GM	853		
Group	Station 7		
log GM	1.7245		
SE	0.4334		
N	5		
GM	53		
Group	Station 8D		
log GM	0.4515		
SE	0.2882		
N	4		
GM	3		
Group	Station 6		
log GM	2.4566		
SE	0.1307		
N	5		
GM	286		
Group	Station 49		
log GM	1.6742		
SE	0.4447		
N	5		
GM	47		

Table 4a - continued

SURVEY	JUNE	AUGUST	SEPTEMBER-OCTOBER
Group	Station 35D		
log GM	0.6475		
SE	0.2643		
N	5		
GM	4		
Group	Station 40A		
log GM	1.8554		
SE	0.4731		
N	5		
GM	72		
Group	Station 47D		
log GM	0.2258		
SE	0.2258		
N	4		
GM	2		

Table 4b

Analysis of Variance Summary of Groups

Parameter - Total coliform TC/100 ml

SURVEY	JUNE	AUGUST
Group	Section 2 Stations 24 - 27	Section 2 Stations 23 - 28
F	1.0942	1.242
df	3, 16	5, 24
F5%	8.70	2.620
	NSD	NSD
Group	Section 2	Section 2
log GM	1.8102	0.9205
SE	0.1984	0.1596
N	20	30
GM	65	8

Table 5a

Summary of Analysis of Variance - Grouping of Stations

Parameter - Fecal Coliform (FC)/100 ml

SURVEY	JUNE	AUGUST	SEPTEMBER-OCTOBER
Group	Section 1	Section 1	All stations
F	1.367	1.228	1.456
df	46, 185	44, 173	44, 179
F(.05)	1.463	1.464	1.462
	NSD	NSD	NSD
Group	A	Section 1	A
log GM	0.1395	0.0887	0.0572
SE	0.0489	0.0173	0.0104
N	232	218	224
GM	1	1	1

Table 5b

Analysis of Variance Summary of Groups

Parameter - Fecal Coliform (FC)/100 ml

SURVEY	JUNE	AUGUST
Group	Section 2	Section 2
F	0.921	1.680
df	3, 16	5, 24
F5%	8.70	2.620
	NSD	NSD

Group	Section 2 Stations 24 - 27	Section 2 Stations 24 - 27
log GM	0.0672	0.0301
SE	0.0672	0.0159
N	20	30
GM	1	1

Table 6a

Analysis of Variance Summary of Groups

Parameter - Fecal Streptococcus (FS)/100 ml

SURVEY	JUNE	AUGUST	SEPTEMBER-OCTOBER
Group	Section 1	Section 1	All
F	1.547	1.268	2.249
df	46, 185	44, 173	44, 178
F5%	1.463	1.464	1.463
	SD	NSD	SD
Group	A	Section 1	A
	All stations except 33A		All stations except 1, 2, 2A, 33A
F	1.158		0.939
df	45, 180		39, 158
F5%	1.465		1.490
	NSD		NSD
log GM	0.3803	0.4230	0.1000
SE	0.0331	0.0367	0.0179
N	226	218	198
GM	2	3	1
Group	Station 33A		C
			Stations 1, 2, 2A
F			0.0378
df			2, 12
F5%			19.4
			NSD
log GM	1.3698		0.5555
SE	0.2359		0.1360
N	5		15
GM	23		4
Group			Station 33A
log GM			0.8808
SE			0.2391
N			5
GM			8

Table 6b

Summary of Analysis of Variance Grouping of Stations

Parameter - Fecal Streptococcus (FS)/100 ml

SURVEY	JUNE	AUGUST
Group	Section 2	Section 2
F	0.747	0.781
df	3, 16	5, 24
F(.05)	8.70	2.620
	NSD	NSD

Group	Section 2	Section 2
	Stations 24 - 27	Stations 23 - 28
log GM	0.2721	0.2946
SE	0.1945	0.0801
N	20	30
GM	2	2

Table 7a

Summary of Tests of Significance Between Analysis of Variance Groups Within A Survey

Newboro Lakes

June Survey

Parameter - Total Coliform

Group or Station	A	35D	47D
C	t = 1.420 df = 138 t5% = 1.98 NSD		
8D		t = 0.500 df = 7 t5% = 2.365 NSD	t = 0.616 df = 6 t5% = 2.447 NSD
47D		t = 1.173 df = 7 t5% = 2.365 NSD	

Table 7b

Summary of Tests of Significance Between Analysis of Variance Groups Within A Survey

Newboro Lakes

August Survey

Parameter - Total Coliform

Group or Station	Section 1
Section 2	t = 1.140 df = 244 t5% = 1.960 NSD

Table 8a

Summary of Tests of Significance Between Analysis of Variance Groups Between Surveys

Newboro Lakes

Parameter - Total Coliform

SURVEY	Group or Station	AUGUST Section 1	AUGUST Section 2
JUNE	A	t = 13.713 df = 324 t5% = 1.960 SD**	
	Section 2		t = 3.505 df = 48 t5% = 2.021 SD*
SEPTEMBER	A	t = 5.8081 df = 377 t5% = 1.96 SD**	t = 2.058 df = 191 t5% = 1.96 SD*

GLOSSARY OF TERMS

ALKALINITY	:The alkalinity of a water sample is a measure of its capacity to neutralize acids. This capacity is due to carbonate, bicarbonate and hydrozide ions and is arbitrarily expressed as if all of the neutralizing capacity was due to calcium carbonate alone.
ANOXIC	:Refers to conditions when no oxygen is present.
BACKGROUND COLONIES	:Background colonies are other lake water bacteria capable of growing on the total coliform plate, in spite of the inherent restrictive conditions.
CHLORIDE	:Chloride is simply a measure of the chloride ion concentration and is not a measure of chlorination.
CHLOROPHYLL _a_	:A green pigment in plants.
CONDUCTIVITY	:Conductivity is a measure of the waters ability to conduct an electric current and is due to the presence of dissolved salts.
DIATOMS	:Unicellular plants found on all continents and in all types of water where light and nutrients are sufficient to support photosynthesis. They are comprised of two siliceous frustules (cell walls) which have an outer valve (epitheca) fitting over the inner valve (hypotheca) like the lid on a box. The siliceous deposits comprising the frustules vary in regular patterns according to the individual species.
EPILIMNION	:Is the thermally uniform layer of a lake lying above the thermocline. Diagram I.
EUPHOTIC ZONE	:The lighted region that extends vertically from the water surface to the level at which photosynthesis fails to occur due to insufficient light penetration.
EUTROPHIC	:Waters containing advanced nutrient enrichment and characterized by a high rate of organic production.

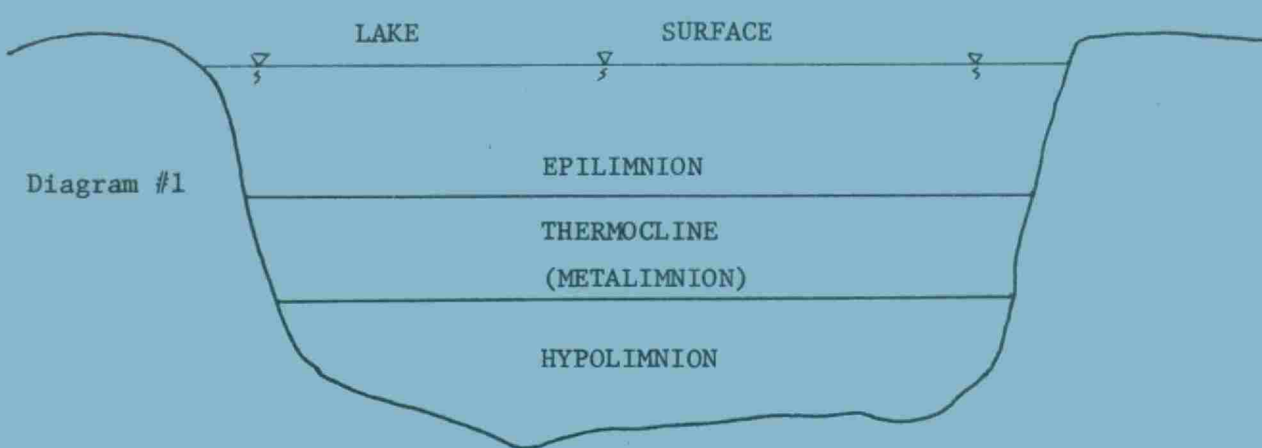
EUTROPHICATION	:The process of becoming increasingly enriched in nutrients. It refers to the entire complex of changes which accompanies increasing nutrient enrichment. The result is the increased production of dense biological growths such as algae and aquatic weeds which generally degrade water quality and render the lake unsuitable for many recreational activities.
FECAL COLIFORMS (FC)	:Fecal coliforms are bacteria associated with recent fecal pollution from man and animals.
FECAL STREPTOCOCCUS (FS)	:Fecal streptococcus are bacteria associated with fecal pollution from animals and to a lesser extent man.
HARDNESS	:Hardness of water is a measure of the total concentration of calcium and magnesium ions expressed as if all of the ions were calcium carbonate.
HYPOLIMNION	:The uniformly cold and deep layer of a lake lying below the thermocline, when the lake is thermally stratified. Diagram #1
KJELDAHL NITROGEN	:Sum of nitrogen present in the ammonia and organic forms (it does not include nitrite or nitrate).
MESOTROPHIC	:Waters characterized by a moderate nutrient supply and organic production (i.e. midway between eutrophic and oligotrophic).
METALIMNION	:See thermocline.
OLIGOTROPHIC	:Waters containing a small nutrient supply and consequently characterized by a low rate of organic production.
pH	:Is the measure of the hydrogen ion concentration expressed as the negative logarithm of the molar concentration.
PHOSPHORUS (TOTAL)	:Sum of all forms of phosphorus present in the sample.

SECCHI DISC : A circular metal plate, 20 centimeters in diameter, the upper surface of which is divided into four equal quadrants. Two quadrants directly opposite each other are painted black and the intervening ones white. The secchi disc is used to estimate the turbidity of the lake water.

THERMAL STRATIFICATION : During the spring, vertical temperatures in a lake are homogeneous from top to bottom. As summer advances, the surface waters become warmer and less dense than the underlying cooler waters. A strong thermal gradient (Thermocline) occurs giving rise to three distinct water layers. The variation in density between layers retards mixing by wind action and water currents. Diagram #1.

THERMOCLINE (metalimnion) : The layer of water located between the epilimnion and hypolimnion in which the temperature exhibits a decline equal to or exceeding 1°C increase per meter.

Diagram #1



TOTAL COLIFORMS (TC) : Total coliforms are bacteria commonly associated with fecal pollution but may also be present naturally in the environment.

TROPHIC STATUS : Depending upon the degree of nutrient enrichment and resulting biological productivity, lakes are classified into three intergrading types:

TROPHIC STATUS (continued)

:oligotrophic, mesotrophic and eutrophic. If the supply of nutrients to an oligotrophic lake is progressively increased, the lake will become more mesotrophic in character and with continued enrichment it will become eutrophic.

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Microbiological Criteria
Water used for body contact recreational activities should be free from pathogens including any bacteria, fungi or viruses that may produce enteric disorders or eye, ear, throat, nose and skin infections. Where ingestion is probable, recreational waters can be considered impaired when the coliform fecal coliform, and/or enterococcus geometric mean density exceeds 1000, 100 and/or 20 per 100 ml respectively, in a series of at least 10 samples per month, including samples collected during weekend periods.

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